Indian Research Journal of Extension Education

RESEARCH ARTICLE

Possibilities in Quality Protein Maize Adoption and its Impact on Food and Nutritional Security in India

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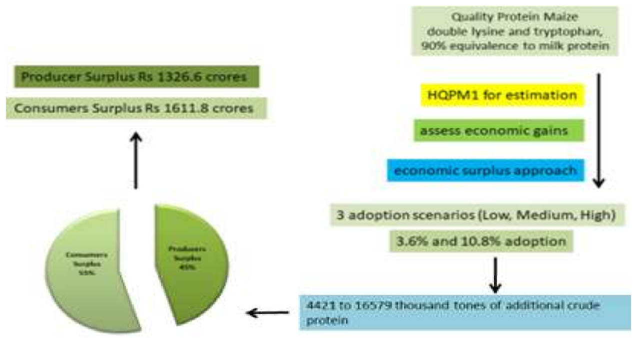
HIGHLIGHTS

- Measured economic benefits of adopting QPM, showcasing increased maize production and protein yield
- Quantified added crude protein, lysine, and tryptophan for the poultry sector.
- Identifies key regions (Zone V, Zones III, II, and IV) for substantial gains, guiding targeted QPM adoption efforts.

GRAPHICAL ABSTRACT



ARTICLE INFO

Editor:
Dr. T, Rajula Shanthy

Key words:
Malnutrition, Quality protein maize (QPM), Economic surplus approach, Poultry sector, Sustainable agriculture

Received : 15.01.2024
Accepted : 28.02.2024
Online published : 01.04.2024

doi: 10.54986/irjee/2024/apr_jun/1-9

ABSTRACT

Context: Malnutrition, exacerbated by the unaffordability of high-quality animal-based protein sources, affects a significant portion of the global impoverished population. The imperative need for sustainable solutions prompts a shift towards increasing the production of plant-based protein sources.

Objective: This study aims to assess the potential economic benefits of adopting Quality Protein Maize (QPM), with a specific focus on the single cross-hybrid variety HQPM1, using an economic surplus approach.

Methods: The study employs an economic surplus approach to evaluate the economic gains from adopting QPM. Utilizing HQPM1 as a case study, three adoption scenarios are simulated, showing potential gains in maize production, protein yield, and benefits to the poultry sector.

Results & Discussion: Replacing traditional maize with HQPM1 could increase annual production by 150 to 451 thousand tons. Adoption scenarios indicate potential additional gains of 10048 to 37680 thousand tons of maize protein, benefiting the poultry sector with significant increases in crude protein, lysine, and tryptophan. Consumer and producer surplus could rise substantially with varying adoption levels.

Significance: The study recommends the widespread adoption of quality protein maize as a strategic approach to ensure nutritional security. Scaling up adoption to 10.8% of the total maize growing area could yield substantial economic benefits, emphasizing the potential of QPM to address malnutrition and contribute to economic growth.

The world food scenario at this moment is being rapidly redefined by new driving forces. Climate change, globalization, income growth, high energy prices and urbanization are altering food consumption, production, and markets. A Trinity of changes in food availability, rising commodity prices, and new producer-consumer linkages have made crucial implications nowadays for the livelihoods of poor, food-insecure and undernourished people (Braun, 2007). In the developing world, the number of undernourished has increased from 823 million in 1990 to 830 million in 2004 (FAO, 2006). The share of the ultra-poor those who live on less than US $ 0.50 a day decreased more slowly than the share of the poor who live on US $ 1 a day. The situation is quite different in Sub-Saharan Africa and Latin America where the number of people living on less than US $ 0.50 a day has increased (Ahmed *et al.***,** 2007). Undoubtedly, the poorest are being left behind (Braun, 2007). According to UNICEF (2018), in the major developing world, one of every three children under the age of five is stunted. Children living in rural areas are nearly twice as likely to be underweight as children in urban areas. Nearly half of all deaths in children under 5 are attributable to undernutrition, translating into the loss of about 3 million young lives a year.

A similar case can be found in India like other developing countries. In India about 40 percent of children under the age of 5 years are underweight and child mortality is also high. Based on such facts, serious questions are now being raised about the country's achievements in food security (Chand et al., 2013). Malnutrition reflects an imbalance of both macro and micro-nutrients that may be due to inappropriate intake and/or inefficient biological utilization due to the internal/external environment, is a major threat to social and economic development and is also correlated to the growing HIV/AIDS pandemic. Malnutrition makes adults more susceptible to the virus and diseases like Kwashiorkar, Marasmus, Marasmic Kwashiorkar *etc.* occur in extreme malnutrition.

According to studies based on per person per day energy norms of 2400 Kcal for rural and 2100 Kcal for urban areas, there is a drop in the prevalence of undernourishment based on energy intake during 1987-88 to 2004- 05 (Deaton and Dreze, 2009). Although the poverty lines were initially associated with a caloric norm income poverty and the prevalence of undernutrition are not moving in the same direction. Among the demographically and activity-wise adjusted calorie norms, the prevalence of undernourishment is higher in rural areas across all the income categories. More than half of the income-poor population is suffering from 'involuntary hunger' in both rural and urban areas across all the choices of norms (Chand *et al.***,** 2013). This situation demands crucial research agendas in agriculture, nutrition, and health aspects (Braun, 2007).

Energy and protein requirements are the key indicators for food and Nutritional security measurements and have been highlighted in several food and nutrition studies. Deaton and Dreze (2008), in their study, have shown the mean per capita consumption of dietary protein and energy is reduced day after day. The per capita consumption of calories and protein is falling in rural India, and shows no trend in urban India; this is occurring against the increase in per capita expenditures of real households. In rural India, household per capita calorie consumption was 2,240 kilocalories in 1983, and fell to 2,047 kilocalories per head in 2004–05, contributing a decline of 8.6 percent from 1983. The urban per capita calorie consumption was only 49 kilocalories (2.4 percent) lower than in 1983. Over the same period, rural and urban per capita protein consumption fell by 12.1 percent and 4.6 percent respectively.

In such a context, cereals have been targeted the most. Cereals are the possible option, due to their major share in the food basket of the world populace and low cost than other animal sources of protein. Cereals supply more than half of the dietary protein to human beings. Among all other cereals, maize is a globally important cereal that acts as a source of protein whereas animal sources are not affordable. Maize grain accounts for about 15 to 56% of the total daily calories in the diets of people in about 25 developing countries, particularly in Africa and Latin America (FAO, 1992), where animal protein is scarce and expensive and consequently, unavailable to a vast sector of the population.

Maize, being rich in essential minerals such as potassium, phosphorus, calcium, magnesium, and iron, plays a vital role in meeting daily nutritional requirements. However, conventional maize varieties often fall short of providing adequate protein quality, mainly due to low levels of essential amino acids like lysine and tryptophan. This deficiency affects the biological value of maize protein, impacting its availability and utilization in the body.

The development of QPM hybrids, including HQPM1, aims to address these shortcomings by significantly increasing the levels of lysine and tryptophan while reducing leucine content. Such improvements enhance the nutritional profile and biological value of maize, making it a more viable option for combating malnutrition. India's efforts in developing various QPM cultivars, such as Shakti, Rattan, Protina, and the HQPM1 hybrid, demonstrate advancements in agricultural research towards improving nutritional outcomes. The selection of HQPM1 for economic assessment reflects its potential to not only enhance maize production but also contribute to broader food security initiatives, thus underscoring its significance in addressing global malnutrition challenges. The study explores the nutritional and biological significance of Quality Protein Maize (QPM), with a specific focus on the HQPM1 hybrid variety, in addressing malnutrition and enhancing food security.

This study explores the potential of Quality Protein Maize (QPM), with a specific emphasis on the HQPM1 hybrid variety, in mitigating malnutrition and fortifying food security, particularly within socioeconomically challenged regions. Our hypothesis was widespread adoption of Quality Protein Maize (QPM), specifically the HQPM1 hybrid variety, will lead to significant economic gains and improved food and nutritional security in India.

METHODOLOGY

Data regarding the area, production, yield, maize, and state-wise farm harvest prices all over India were collated from the Directorate of Economics and Statistics database (DES, 2016-17). The state-wise average area, production, yield under maize and value of production were gathered from DES, 2016-17 database. The cost of cultivation of maize in different states of India was taken from DES for the last three years (2014-15 to 2016-17).

For the present study *ex post* impact assessment was undertaken for HQPM1 cultivar of quality protein maize. The economic surplus method is aimed at measuring the aggregate social benefits of a particular research project. It is the most popular method for measuring social benefits as requires the least data and can be applied to the broadest range of situations (Alston *et al*., 1995). The changes in economic surplus due to yield improvement have been illustrated in Figure 1. Adoption of a yield-increasing variety shifts maize supply curve downwards, from S_0 to S_1; and the demand curve for maize and its products is assumed to remain unchanged at C_0. The price of maize is determined by the world market at P_0 and will not change due to an increase in domestic production. Consumer surplus, thus, remains constant, and the entire benefits from the adoption of the improved variety accrue to the producers. In this figure, the producer surplus increases equal to the area 'abcd'. Mathematically, the change in producer surplus in a small open economy can be represented by Equation 1:

$$\Delta PS_t = \Delta TS_t = P_0Q_0 (K_t - Z_t) (1+0.5\, Z_t\eta) \ldots(1)$$

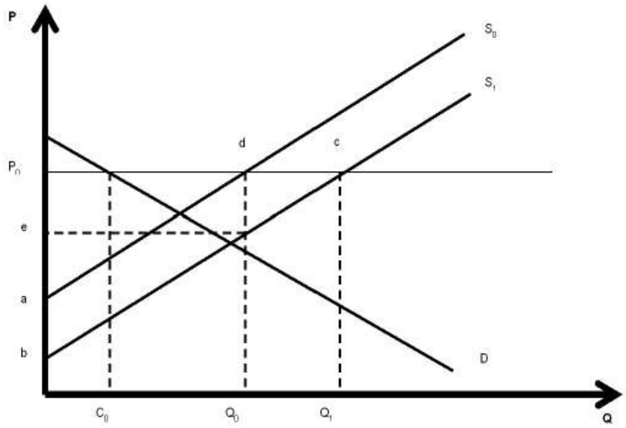


Fig 1. Economic surplus due to yield improvement in an open economy framework

where ΔPS_t is the change in producer surplus in the year t; “TS_t is the change in total surplus in the year t; P_0 is the initial price; Q_0 is the initial level of production; Z_t is the reduction in price in the year t as a result of an increase in supply due to adoption of improved variety; η is the absolute value of demand elasticity and K_t is the proportionate supply shift in the year t due to adoption of improved variety. The value of K_t can be obtained as:

$$K_t = \{[E(Y)] / \varepsilon - [E(C)] / [1 + E(Y)]\}\ \rho A_t (1 - \delta_t) \ldots(2)$$

where, E(Y) is the change in yield per ha, E(C) is the change in variable cost per ha to achieve the yield change; ε is the supply elasticity; ρ is the success rate or probability of success in achieving the expected yield; A_t is the adoption rate in the year t and δ_t is the depreciation on the improved variety that is a reduction in expected yield in the year t.

The potential economic benefit of HQPM1 and its distribution between producers and consumers have been estimated using this method. To simulate the potential benefits apart from the area, production, yield, and average price, yield gain of HQPM1 over existing local check varieties of hybrid maize, reduction of cost of production, price elasticity of demand and supply and adoption scenario were calculated.

Maize is a diversified crop produced in almost every state of the country except Kerala. The entire maize area of the country is divided into five major zones (zone I, zone II, zone III, zone IV and Zone V) by the Directorate of Maize Research based on the climatic condition for effective evaluation of maize breeding materials and experimental cultivars. To capture agro-climatic variability, these five maize-growing zones were taken into consideration (Fig 2). The zone-wise average maize price was calculated by the weighted average price data of the last three years (2014-15 to 2016-17) where the share of production of respective states was used as weight criteria.

As HQPM1 is a single cross hybrid and Karnataka and Andhra Pradesh states have comparatively more area coverage under single crossed hybrid maize than others, the average cost of production of maize in these states has been taken as a proxy for QPM cost of production.

The state-wise average cost of production was calculated for the last three years (2014-15 to 2016-17) to reduce externalities. Afterward, zone-wise reduction of average cost of production was calculated where the share of production of respective states was used as weight criteria.

As far as price elasticity is concerned, as maize is a coarse cereal so price elasticity of demand for coarse cereals has been taken from Kumar *et al.* (2011), and supply response elasticity was taken of rice as a proxy of maize from Kumar *et al*. (2010).

The economic gains of HQPM1 have been simulated under 3 scenarios all over India and zone-wise. For different zones, rates of adoption are considered differently (Table 1) as per breeders' and experts' opinions. The Delphi technique was used to simulate the zone-wise rate of adoptions under low, medium and high adoption scenarios. In the case of all over India, it has been simulated at 3.6%, 7.1% and 10.8% for low, medium and high adoption scenarios.

RESULTS

In this section, we present the results of our study, which underscore the advantages of adopting HQPM1 to boost maize production in India, benefiting both farmers and consumers. We examine the potential

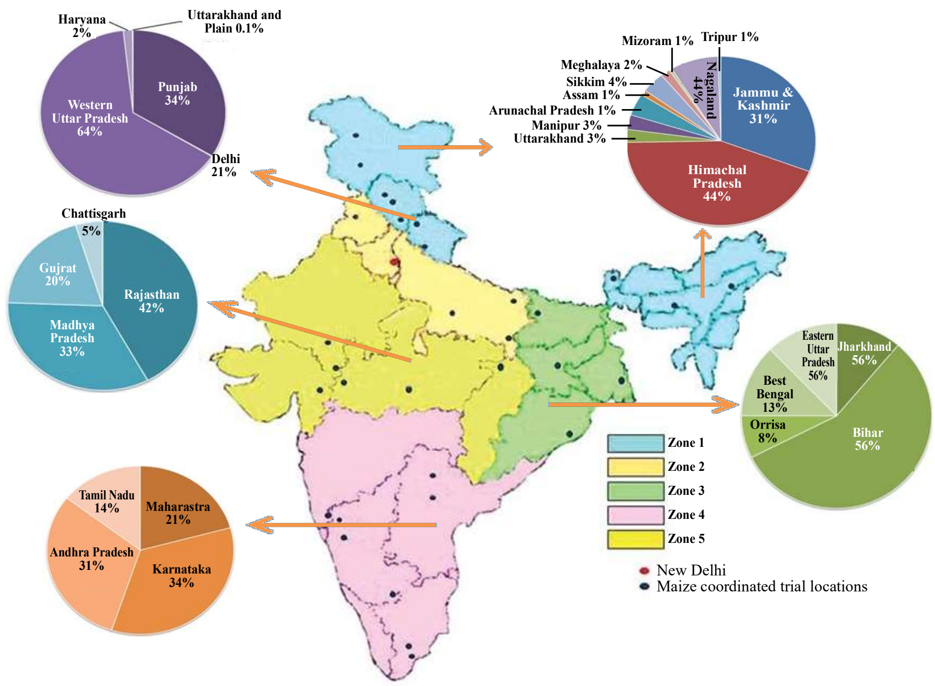


Fig 2 . Maize growing zones in India and state-wise share of production in each zone

Note: There are five major maize-growing zones in India. Among these zones, Zone 4 (Andhra Pradesh, Karnataka, Maharashtra and Tamil Nadu) contributes 55% of overall maize production in India followed by Zone 5 (18%), Zone 3 (13%), Zone 1 (7.2%) and Zone 2 (6.8%).

Source: DMR, 2017-18; the production share of the respective state in data from agri.coop.nic.in, the year 2016-17.

Table 1. Summary of data for simulation of economic gains from HQPM1 in different maize zones in India

Particulars	Zone I	Zone II	Zone III	Zone IV	Zone V	India
Production ('000 tonnes)	1726.5	1594.4	3098.5	13425.4	4325.2	24170
Area ('000 ha)	801.3	668.3	1208.4	3178.49	2604.3	8460.79
Price (₹/kg)	10.10	8.96	7.20	8.58	8.85	8.60
Yield gain (%) as compared to zonal check	29.36	24.84	24.47	17.66	13	19.1
Reduction in cost of production (%)	-0.03	0.50	0.13	0.07	0.39	0.16
Price elasticity of demand	-0.194	-0.194	-0.194	-0.194	-0.194	-0.194
Price elasticity of supply	0.2357	0.2357	0.2357	0.2357	0.2357	0.2357
Area adoption (%)						
Low adoption scenario	0.75	7.5	6.205	1.57	4.79	3.6
Medium adoption scenario	1.55	14.96	12.41	3.14	9.59	7.1
High adoption scenario	2.325	22.44	18.615	4.71	14.385	10.8

Sources: Production, area and price and cost of cultivation data have been collated from DES (2016) and CMIE (2016); Data regarding yield gain has been gathered from HQPM1 variety release proposal and AICRP (2009); Price elasticity of demand has been taken from Kumar et al., (2011) whereas Price elasticity of supply from Kumar et al., (2010) and adoption rates are based on breeder and experts perspective.

benefits of Quality Protein Maize (QPM) cultivation across various regions in India, particularly focusing on the economic surplus generated by HQPM1 under different scenarios within maize-growing zones. Through simulation, we analyze the projected gains in economic surplus attributable to HQPM1 adoption across diverse maize cultivation zones in India.

Benefits to farmers : The maize grower will benefit due to a considerable increase in productivity which will lead to higher production and increased income per unit area. Corresponding to the assumed adoption level of HQPM1, maize output to the tune of 166 thousand tonnes to 623 thousand tonnes can be added to total production from the existing area under maize in India (Table 2). The net return would be 143 crores at 4 percent adoption level and will reach 536 crores at 15 percent adoption level.

Benefits to consumers : The adoption of HQPM1 would benefit the consumer in terms of additional gains in protein and essential amino acids like lysine and tryptophan which remain in very poor quantity in normal maize. The increased amount of lysine and tryptophan will enhance the biological value of maize protein and it would be equivalent to 90 per cent of milk protein which was earlier 50 per cent in the case of normal maize. The study revealed that consequent to the assumed adoption level of HQPM1, likely additional gains of maize protein will be 10048, 20096 and 37680 thousand tonnes in low, medium and high adoption scenarios respectively (Table 2). Along with this lysine and tryptophan in the tune of 1450 and 207 thousand tonnes respectively in low adoption to 5438, and 777 thousand tonnes respectively in high adoption scenario can be gained. These will help in improving the food and nutritional security of resource-poor consumers.

Sector-wise benefits : The table illustrates the sector-wise gains in crude protein resulting from different adoption levels of the technology. Among these sectors, poultry feed stands out as the primary beneficiary, with the potential to accrue substantial

Table 2. Potential benefits of QPM cultivation in India in a production year

Particulars	Scenarios: Adoption level		
Benefits to farmers	Low (< 3.6%)	Medium (<7.1%)	High (<10.8%)
i) Increase in Production (‘000 tonnes)	150.03	300.47	450.92
ii) Increase in net returns (in crores)	129.03	258.41	387.79
Benefits to Consumers (in ‘000 tonnes)			
Likely gains of maize crude protein	10048.18	20096.37	37680.69
Sector wise gain of crude protein (in ‘000 tonnes)			
Poultry feed	4421.19	8842.40	16579.2
Food	2411.56	4823.12	9043.36
Livestock feed	1607.70	3215.40	6028.91
Industry	1607.70	3215.40	6028.91

benefits. Adoption of the technology could yield additional crude protein ranging from 4421 to 16579 thousand tonnes, accompanied by an increase in lysine and tryptophan ranging from 638 to 2393 thousand tonnes and 91 to 342 thousand tonnes, respectively. Following poultry feed, the human food sector emerges as the next significant beneficiary, with potential gains ranging from 2411 to 9043 thousand tonnes of crude protein. The livestock feed sector and industry also stand to benefit, with additional crude protein ranging from 1607 to 6028 thousand tonnes under varying adoption scenarios. Overall, these findings highlight the considerable potential for enhancing protein production and addressing nutritional deficiencies across multiple sectors through the adoption of this technology.

Potential economic gain : The potential economic gains to farmers and consumers owing to the adoption of HQPM1 had also been estimated in terms of economic surpluses. The adoption of HQPM1 could raise consumer surplus by 1611.8 crores and producer surplus by 1326.6 crores with a 3.6% adoption level (Table 3). If the adoption level reaches 10.8 % of the total maize growing area, consumer surplus would be increased up to 4877.6 crores and producer's surplus up to 4014.66 crores. The gains in economic surplus would be distributed between consumer and producer in the ratio of 55:45.

In absolute terms, the likely gains to the total economy have been estimated between 2938.4 crores to 8892.27 crores, corresponding to different levels of adoption. It is an enormous benefit in absolute terms for maize-like crops with average area coverage much smaller than that of rice and wheat.

Zone wise economic gain : There are five maize-growing zones in India. To know the zone-wise economic surplus, further efforts have been made (Table 4). The largest share in the overall gain may accrue in Zone V followed by Zone III, Zone II and Zone IV.

In zone V the total economic surplus would be approximately 768 crores in the low adoption scenario to 2418 crores in the high adoption scenario. The main reasons behind the difference in total economic surplus across the zones are different area coverage, yield, yield difference with HQPM1 and most importantly the area of adoption.

DISCUSSIONS

Contribution to agriculture and economy of India : The adoption of HQPM1 offers substantial benefits for both farmers and consumers, aligning with previous research highlighting the economic impact of improved crop varieties (Ghosh, 2015; Yadav

Table 3. Simulated gains of economic surplus from HQPM1 under different scenarios in maize growing zones in India (in crore ₹)

Scenario	Total Economic Surplus	Distribution of Economic Surplus	
		Consumers	Producers
Low adoption (3.6 %)	2938.4	1611.8	1326.6
Medium adoption (7.1%)	6566.47	3601.79	2964.56
High adoption (10.8%)	8892.27	4877.6	4014.66

Table 4. Simulated gains of economic surplus from HQPM1 under different scenarios of maize growing zones in India (in crore ₹)

Maize growing zones	Low adoption scenario			Medium adoption scenario			High adoption scenario		
	TS	PS	CS	TS	PS	CS	TS	PS	CS
Zone I	75.52	34.1	41.42	147.34	66.52	80.82	226.68	102.34	102.34
Zone II	657.18	296.66	360.42	1315.21	593.8	721.41	1992.15	899.41	1092.74
Zone III	705.55	318.54	387.01	1415.02	638.85	776.17	2183.71	985.9	1197.81
Zone IV	579.12	261.46	317.66	1167.62	527.52	640.1	1742.84	786.85	955.1
Zone V	767.9	346.69	421.21	1490.31	672.9	817.41	2418.13	1091.73	1326.4
India	2785.27	1257.45	1527.72	5535.5	2499.59	3035.91	8563.51	3866.23	4674.39

Note: TS, PS and CS denote Total Surplus, Producer Surplus and Consumers Surplus respectively.

et al., 2016a). This study estimates a considerable increase in maize productivity, leading to higher production and income per unit area for farmers, consistent with findings from similar studies on high-yielding crop varieties adoption. The zone-wise economic analysis underscores the differential impact of HQPM1 adoption across various maize-growing zones, reflecting regional disparities often observed in agricultural interventions (Yadav et al., 2016b). Zone V (Madhya Pradesh, Rajasthan, Gujarat, and Chattisgarh) emerges as the major beneficiary, highlighting the importance of tailored interventions to specific agroecological zones.

The sector-wise impact of HQPM1 adoption, particularly in the poultry feed, food, livestock feed, and industrial sectors, has been highlighted, with the poultry sector emerging as the primary beneficiary, in line with global trends (Mukherjee et al., 2019). Potential gains in crude protein, lysine, and tryptophan are crucial for the poultry sector, emphasizing the importance of biofortified crops in enhancing animal nutrition (Yadav *et al*., 2016b). For consumers, HQPM1 adoption brings additional gains in protein and essential amino acids, particularly lysine and tryptophan, with potential implications for addressing malnutrition, especially in regions where maize is a staple food (Hossain *et al.*, 2017, 2019).

The study establishes that lysine and tryptophan levels in HQPM1 are significantly higher than in normal maize, contributing to improved biological value comparable to milk protein, consistent with findings of studies emphasizing the nutritional benefits of biofortified crops (Swayamprava *et al*., 2024). The economic surplus analysis further reinforces the positive outcomes of HQPM1 adoption, with consumer and producer surpluses increasing significantly with higher adoption levels, indicating the potential for widespread economic benefits, as observed in other agricultural contexts (Gohar *et al*., 2021). The ratio of consumer to producer surplus in the study (55:45) aligns with the distribution observed in other agricultural contexts.

Contribution to human health and child nutrition

The discussion on child malnutrition connects the research to a broader societal context. The study recognizes the high prevalence of malnutrition in India, specifically among children. This aligns with existing literature emphasizing the role of crop improvement in addressing nutritional deficiencies (Satyapriya et al., 2020). The potential health benefits of QPM, as discussed, underscore its role in combating malnutrition, especially among vulnerable populations. This nutritional enhancement has potential implications for addressing malnutrition, especially in regions where maize is a staple food (Hossain et al., 2017, 2019). The study establishes that lysine and tryptophan levels in HQPM1 are significantly higher than in normal maize, contributing to an improved biological value comparable to milk protein. Such improvements in protein quality resonate with the findings of studies emphasizing the nutritional benefits of biofortified crops (Swayamprava *et al*., 2024).

The potential health benefits of QPM align with previous research on biofortification and nutrient-dense crops. QPM's higher lysine and tryptophan content, as well as improved amino acid balance, make it a promising solution to combat nutrient deficiencies (Sharma and Jain, 2015). The study contributes to the understanding of QPM's nutritional advantages, complementing existing literature on the impact of biofortified crops on human health (Swayamprava *et al*., 2024).

The diversification of QPM-based products further enhances its potential impact on nutrition and food security. By developing a wide array of products, including traditional and value-added items, the study aligns with the growing body of literature emphasizing the importance of crop diversification for sustainable food systems (Yadav *et al.,* 2006). Additionally, blending QPM with legumes contributes to the development of protein-rich products, aligning with strategies to improve protein quality and quantity in diets.

Challenges: Adoption and Market Dynamics : Navigating the adoption and market dynamics of Quality Protein Maize (QPM) varieties presents a multifaceted challenge rooted in both agricultural and economic realms. Adoption rates of QPM varieties are influenced by numerous factors including farmer knowledge, access to seeds, agronomic practices, and perceived benefits compared to traditional maize cultivars. The issues related to isolation distance, pest infestation, and seed production further underscore the complexities in ensuring the successful adoption and dissemination of improved crop varieties (Prasad, 2016, Maqbool *et al*., 2021). Educational initiatives and extension services are crucial for disseminating information and promoting the advantages of QPM varieties among farmers, thereby facilitating adoption.

Furthermore, addressing market dynamics is pivotal for ensuring the sustained cultivation and commercial success of QPM varieties. Market factors such as price fluctuations, demand-supply dynamics, and consumer preferences play a significant role in determining the viability and profitability of QPM cultivation. The lack of a premium price for QPM grains in the market is a significant concern, emphasizing the importance of market incentives in promoting the adoption of improved varieties (Yadav *et al*., 2016, Bidi *et al*., 2019). Strategies to enhance market acceptance and incentivize adoption may include value chain development, market linkages, and targeted marketing campaigns highlighting the nutritional benefits of QPM. Additionally, policy interventions and regulatory frameworks can shape market dynamics by providing incentives for QPM cultivation and promoting its inclusion in food programs. Overcoming these challenges requires a comprehensive approach that integrates agricultural, economic, and policy dimensions to foster widespread adoption and market integration of QPM varieties, ultimately contributing to improved food security and nutrition outcomes.

CONCLUSION

In the face of constrained economic resources, the necessity of justifying investments, particularly in agricultural research, cannot be overstated for governments and foreign aid donors. Rigorous economic studies play a pivotal role in quantifying and comparing the long-term benefits of such research endeavours. This study, through its comprehensive economic assessment, aims to elucidate the tangible returns from agricultural research, thereby facilitating informed decision-making and efficient resource allocation.

In the context of India, where malnutrition persists due to the unavailability of affordable alternative protein sources, the introduction of Quality Protein Maize (QPM) emerges as a transformative step for development. Despite the challenges posed by limited resources, the urgent need to bridge the gap between per capita protein consumption and daily requirements underscores the importance of sustainable solutions, with QPM poised to play a pivotal role in this endeavour. The research highlights the untapped potential of maize in India, particularly through the adoption of QPM varieties like HQPM1, which offer elevated lysine and tryptophan content to address nutritional deficiencies effectively. Moreover, the distribution of benefits across different regions underscores the significant impact that QPM adoption can have, particularly on impoverished states. This necessitates focused efforts in technology dissemination, marketing, and product promotion to ensure sustainable welfare gains.

To maximize the nutritional benefits of QPM, policy interventions should prioritize sensitizing the food processing and value-addition industry about its advantages. Popularizing QPM products, ensuring consistent supply through mechanisms like contract farming, and implementing a "QPM seed village" approach can significantly enhance accessibility and adoption rates. Additionally, enhancing post-harvest management and extending the shelf life of QPM grains are imperative steps. Furthermore, raising awareness among the poultry industry about the advantages of yellow QPM grains and conducting intensive campaigns targeting consumers can play a pivotal role in bolstering nutritional security nationwide.

*Funding :*There was no funding support for conducting this research.

*Declaration of competing interest :*The authors have no known competing interests.

Data availability: Data would be made available on request

Appendix: Supplementary data: The supplementary data, table, and graph in jpeg format for online visibility to the readers are submitted as an appendix.

*Author's Contribution:*The first five authors conceptualized, operationalized, analyzed the data and interpreted the data. The sixth seventh and tenth authors collected and collated the data and helped in analysing the data. The eighth and ninth authors participated in contributing to the text and the content of the manuscript, including revisions and edits. The authors approve of the content of the manuscript and agree to be held accountable for the work.

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